CLAIMS

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1. A method for determining a property of a material, comprising the steps of:

(a) inducing, within said material, gamma radiation comprising energies greater than about 3 MeV;

(b) measuring a first gamma ray spectrum and a second gamma ray spectrum resulting from said induced gamma radiation;

(c) normalizing said first and said second gamma ray spectrum in a first energy region;

(d) measuring down scatter gamma radiation in a second energy region of said normalized first and second gamma ray spectra; and

(e) determining said property from said measure of down scatter radiation.

2. The method of claim 1 comprising the additional step of forming said induced gamma radiation by means of a neutron source.

3. The method of claim 2 wherein:

(a) said first gamma ray spectrum is measured at a first distance from said neutron source;

(b) said second gamma ray spectrum is measured at a second distance from said neutron source wherein said second distance is greater than said first distance;

(c) said first energy region comprises gamma radiation with energy greater than gamma radiation in said second energy region;

(d) said second gamma ray spectrum is normalized to said first gamma ray spectrum thereby forming a normalized second gamma ray spectrum; and

(e) said property is determined from a difference in said down scatter radiation in said second energy regions of said first gamma ray spectrum and said normalized second gamma ray spectrum.

4. The method of claim 1 wherein said property is bulk density.

5. The method of claim 1 wherein said material is earth formation penetrated by a borehole.

6. The method of claim 5 comprising the additional step of measuring said property as a function of depth within said borehole by conveyance of apparatus along said borehole by means of a wireline.

7. The method of claim 5 comprising the additional step of measuring said property as a function of depth within said borehole by conveyance of apparatus along said borehole by means of a drill string.

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8. A method for determining a property of a material, comprising the steps of:

(a) inducing gamma radiation within said material by means of a neutron source;

(b) measuring a first gamma ray spectrum resulting from said induced gamma radiation at a first spacing from said neutron source;

(c) measuring a second gamma ray spectrum resulting from said induced gamma radiation at a second spacing;

(d) normalizing said second gamma ray spectrum to said first gamma ray spectrum in a first energy region thereby creating a normalized second gamma ray spectrum; and

(e) combining said first gamma ray spectrum with said normalized second gamma ray spectrum in a second energy region to determine a measure of said property.

9. The method of claim 8 wherein said second spacing is greater than said first spacing.

10. The method of claim 9 wherein:

(a) said first energy region ranges from about 3 MeV to about 7 MeV; and

(b) said second energy region ranges from about several hundred keV to about 3 MeV.

11. The method of claim 8 wherein said first gamma ray spectrum in said second energy region is subtracted from said normalized second gamma ray spectrum in a second energy region to determine said measure of said property.

12. The method of claim 8 wherein said neutron source comprises Californium-252.

13. The method of claim 8 wherein said property is bulk density.

14. The method of claim 13 comprising the additional steps of:

(a) identifying one or more elements within said material from said first gamma ray spectrum and said second gamma ray spectrum;

(b) determining lithology of said material from said one or more elements; and

(c) correcting said measure of bulk density for effects of said lithology of said material.

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15. The method of claim 8 wherein said material is earth formation penetrated by a borehole.

16. The method of claim 15 comprising the additional step of conveying apparatus used to obtain said measure of said property within said borehole by means of a wireline.

17. The method of claim 15 comprising the additional step of conveying apparatus used to obtain said measure of said property within said borehole by means of a drill string.

18. An apparatus for measuring a property of a material, comprising:

(a) a neutron source;

(b) a first gamma ray spectrometer displaced from said source at a first axial spacing and which measures a first gamma ray spectrum resulting from gamma radiation induced within said material by said neutron source;

(c) a second gamma ray spectrometer displaced from said source at a second axial spacing and which measures a second gamma ray spectrum resulting from said gamma radiation induced within said material by said neutron source; and

(d) a processor for

(i) normalizing said second gamma ray spectrum to said first gamma ray spectrum in a first energy region thereby creating a normalized second gamma ray spectrum, and

(ii) combining said first gamma ray spectrum with said normalized second gamma ray spectrum in a second energy region to determine a measure of said property.

19. The apparatus of claim 18 wherein said property is bulk density.

20. The apparatus of claim 18 wherein said induced gamma radiation comprises energies greater than about 3 MeV.

21. The apparatus of claim 18 wherein said second spacing is greater than said first spacing.

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22. The apparatus of claim 18 wherein:

(a) said first energy region ranges from about 3 MeV to about 7 MeV;

(b) said second energy region ranges from about several hundred keV to about 3 MeV; and

(c) said first gamma ray spectrum in said second energy region is subtracted from said normalized second gamma ray spectrum in said second energy region to determine said measure of said property.

23. The apparatus of claim 18 wherein said neutron source comprises Californium-252.

24. The apparatus of claim 18 wherein said material is earth formation penetrated by a borehole.

25. The apparatus of claim 24 comprising means for conveyance along said borehole by a wireline.

26. The apparatus of claim 24 comprising means for conveyance along said borehole a drill string.

27. A method for determining bulk density of an earth formation penetrated by a borehole, the method comprising the steps of:

(a) inducing gamma radiation within said formation by means of a neutron source;

(b) measuring gamma ray counts resulting from said induced gamma radiation in a low energy window extending from about several hundred keV to about 3 MeV at a first axial spacing

from said neutron source;

(c) measuring gamma ray counts resulting from said induced gamma radiation in a high energy window extending from about 3 MeV to above 7 MeV at said first axial spacing;

(d) measuring gamma ray counts resulting from said induced gamma radiation in said low energy window at a second axial spacing from said neutron source, wherein said second spacing is greater than said first axial spacing;

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(e) measuring gamma ray counts resulting from said induced gamma radiation in said high energy window at said second axial spacing;

(f) computing a normalization factor by dividing said gamma ray counts measured at said first spacing in said high energy window by said gamma ray counts measured at said second axial spacing in said high energy window;

(g) computing a normalized gamma ray count for said low energy window at said second axial spacing by multiplying said normalization factor by said gamma ray counts measured in said low energy window at said second axial spacing;

(h) computing a low energy window count difference by subtracting said gamma ray count measured at said first axial spacing in said low energy window from said normalized gamma ray count;

(i) correcting said low energy window count difference for effects of formation lithology to form a corrected low energy window count difference; and

(j) determining said bulk density from said lithology corrected low energy window count difference using a predetermined functional relationship.

28. An apparatus for determining bulk density of an earth formation penetrated by a borehole, the apparatus comprising:

(a) a Californium-252 neutron source which induces gamma radiation within said earth formation comprising energies ranging from about several hundred keV to about 10 MeV;

(b) a short spaced gamma ray spectrometer displaced from said source at a first axial spacing and which responds to gamma radiation induced within said earth formation by said neutron source;

(c) a long spaced gamma ray spectrometer displaced from said source at a second axial

spacing and which responds to said gamma radiation induced within said earth formation by said neutron source, wherein said second axial spacing is greater than said first axial spacing; and

(d) a processor which is preprogrammed to

(i) store gamma ray counts detected by said short spaced spectrometer and resulting from said induced gamma radiation in a low energy window extending from about several hundred keV to about 3 MeV at a first axial spacing from said neutron source,

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(ii) store gamma ray counts detected by said short spaced spectrometer and resulting from said induced gamma radiation in a high energy window extending from about 3 MeV to above 7 MeV at said first axial spacing,

(iii) store gamma ray counts detected by said long spaced spectrometer and resulting from said induced gamma radiation in said low energy window,

(iv) store gamma ray counts detected by said long spaced spectrometer and resulting from said induced gamma radiation in said high energy window,

(v) compute a normalization factor by dividing said gamma ray counts measured by said short spaced spectrometer in said high energy window by said gamma ray counts measured by said long spaced detector in said high energy window,

(vi) compute a normalized gamma ray count for said low energy window in said long spaced spectrometer by multiplying said normalization factor by said gamma ray counts measured in said low energy window in said long spaced spectrometer,

(vii) compute a low energy window count difference by subtracting said gamma ray count measured by said short spaced spectrometer in said low energy window from said normalized gamma ray count,

(viii) correct said low energy window count difference for effects of formation lithology to form a corrected low window count difference, and

(ix) determine said bulk density from said lithology corrected low energy window count difference using a predetermined functional relationship.

29. A method for determining bulk density of incident materials, the method comprising the steps of:

(a) inducing gamma radiation within said material by means of a neutron source;

(b) measuring gamma ray counts resulting from said induced gamma radiation in a low energy window extending from about several hundred keV to about 3 MeV at a first axial spacing from said neutron source;

(c) measuring gamma ray counts resulting from said induced gamma radiation in a high energy window extending from about 3 MeV to above 7 MeV at said first axial spacing;

Sub A1 (d) measuring gamma ray counts resulting from said induced gamma radiation in said low energy window at a second axial spacing from said neutron source, wherein said second spacing is greater than said first axial spacing;

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(e) measuring gamma ray counts resulting from said induced gamma radiation in said high energy window at said second axial spacing;

(f) computing a normalization factor by dividing said gamma ray counts measured at said first spacing in said high energy window by said gamma ray counts measured at said second axial spacing in said high energy window;

(g) computing a normalized gamma ray count for said low energy window at said second axial spacing by multiplying said normalization factor by said gamma ray counts measured in said low energy window at said second axial spacing;

(h) computing a low energy window count difference by subtracting said gamma ray count measured at said first axial spacing in said low energy window from said normalized gamma ray count;

(i) correcting said low energy window count difference for effects of the composition to form a corrected low energy window count difference; and

(j) determining said bulk density from said corrected low energy window count difference using a predetermined functional relationship.